Notice No. 1

Rules and Regulations for the Classification of Naval Ships, January 2014

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior notices. Any corrigenda included in the notice are effective immediately.

Issue date: January 2014

Amendments to	Effective date
Volume 2, Part 2, Chapter 2, Sections 1-12	1 January 2014

Lloyd's Register

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Volume 2, Part 2, Chapter 2

Gas Turbines

Effective date January 2014

Existing Chapter 2 has been deleted in its entirety.

■ *Scope*

The requirements of this Chapter are applicable to the design and construction philosophy for gas turbine packages for main propulsion and, where powers exceed 110 kW (150 shp), to those for essential auxiliary services.

This Chapter details the requirements for sub-systems and equipment within the boundary of the gas turbine package for either a direct mechanical drive installation or an integrated electrical power generation system.

Approval will be in respect of the mechanical integrity of the gas turbine (including gas generator and power turbine), intake and exhaust ducting configuration, acoustic enclosure configuration (where appropriate), fuel, lubricating oil and starter systems, control, monitoring, alert and safety systems, and other critical support systems.

The gas turbine bare engine is to be designed and manufactured in accordance with a relevant International or National Standard acceptable to Lloyd's Register (hereinafter referred to as 'LR').

■ *Section 1*

General requirements

1.1 Chapter-specific definitions

1.1.1 Where any of the terms contained within this Section are used within this Chapter, their meaning is to be as defined in 1.1.2 – 1.1.9.

1.1.2 For the purposes of this Chapter, a gas turbine package is part of a larger system (e.g., the propulsion system) providing power for main propulsion, manoeuvring and/or essential support purposes and is considered to be a series of elements, including all equipment and associated sub-systems necessary to provide specified functions within the intended context of use in the system.

1.1.3 The principal elements of a gas turbine package are:

(a) The gas turbine unit, comprising:
  - gas generator (inlet, compressor, combustion system, etc.,);
  - power turbine;
  - engine management bleed air system;
  - accessory gearbox and
  - HP fuel systems.

(b) The on-engine instrumentation and engine control system, the means for monitoring, control and protection of the gas turbine, comprising:
  - hardware, sensors, control cables, processors and cabinets and
  - software.

(c) The gas turbine package installation, comprising:
  - mounting arrangements that support the gas turbine to maintain shaft alignment and which provide the required levels of shock/vibration/noise attenuation; where appropriate, this includes the base frame mounts;
  - package enclosure (where provided), including, where appropriate, the base frame supporting the gas turbine unit (and alternator);
  - package drains;
  - arrangements for lubricating the gas turbine unit and, where relevant, the alternator;
  - arrangements for air cooling of gas turbine and equipment;
  - combustion air inlet plenum and exhaust collector;
  - gas turbine start system (off-unit components);
  - fire protection arrangements (covering detection, containment and suppression of fire);
  - intercooler and recuperator systems fitted to the gas turbine;
  - combustion air filtration and arrangements to prevent ingestion of foreign objects;
  - package control system, the means for monitoring, control and protection of the package, including arrangements for maintaining its power supply against loss of ship's supply.

(d) For an integrated gas turbine generator unit, the gas turbine package also includes:
  - alternator, including arrangements for its ventilation/cooling and bearing lubrication and for voltage/frequency control plus
  - high speed coupling shaft (alternator drive shaft).

A gas turbine system consists of the gas turbine unit plus its control, monitoring, alert and safety systems. *See* (a) and (b).

1.1.4 Essential support services/ship interfaces include:

(a) combustion air supply ducting;
(b) exhaust ducting;
(c) provisions for package ventilation/air cooling;
(d) ship's cooling water supply;
(e) ship's drains;
(f) fuel supply system;
(g) electrical power supplies for engine operation, including connections to/from uninterruptible power supplies;
(h) appropriate connections with the ship's control, monitoring, alert and safety systems for remote monitoring/control of the gas turbine package;
(j) provision to duct away engine bleed air and
(k) arrangements for wet washing gas turbines, supply of washing water and detergents/cleaning agents, and collection arrangements for dirty wash water.

1.1.5 Safety critical systems/components are those which provide functions intended to protect persons from physical hazards caused by engineering system failures, e.g., fire, explosion, or to prevent mechanical damage which may result in the loss of a Mobility Category System.

1.1.6 A Platform Management System provides centralised access to the ship's control, monitoring, alert and safety system functionalities.

1.1.7 Concept of Operations. The Concept of Operations (ConOps) is a statement of an Owner's/Operator's intentions for the operation of the ship. The ConOps describes the ship's intended service in terms of purpose and function and is to include, but is not to be limited to, information on the following: crewing, operational speeds, wave heights, displacements, service area, temperatures, motions, aircraft and boat operations, and arrangements under reasonably foreseeable, normal and abnormal conditions. The ConOps is to be provided by the Owner/Operator.

1.1.8 System Operational Concept. A System Operational Concept is a description of the intended operation of a major ship system, that is comprised of sub-systems and equipment referenced within the Rules. The System Operational Concept is to demonstrate that the system's architecture, configuration and criticality meet the requirements of the operational scenarios defined by the ConOps. The System Operational Concept statements are to be agreed between the designer and Owner/Operator.

1.1.9 System Design Description. The System Design Description is a document that describes the design of a system or equipment. The System Design Description details the system's capability and functionality under all normal and reasonably foreseeable abnormal operating and fault conditions. The System Design Description documents are to be agreed between the designer and Owner/Operator.

1.2 Standard reference conditions

1.2.1 Where power, efficiency, heat rate or specific consumption refer to standard conditions (ISO 2314), such conditions are to be:

(a) for the intake air at the compressor flange (compressor intake flare):
  - a total pressure of 101,3 kPa;
  - an ambient temperature of 15°C;
  - a relative humidity of 60 per cent; and

(b) for the exhaust at the turbine exhaust flange (or recuperator outlet):
  - a static pressure of 101,3 kPa.

■ *Section 2*
Functional requirements

2.1 Functional requirements

2.1.1 The gas turbine package is to operate safely to provide power to ship systems as and when required by the command whilst remaining within the designed or imposed limitations.

■ *Section 3*
Performance requirements

3.1 Performance requirements

3.1.1 The gas turbine package is to be designed and constructed to operate in all normal and reasonably foreseeable abnormal operating and fault conditions.

3.1.2 The choice of materials and components of construction, as well as the design, location and ship installation, is to be made according to the environmental, maintenance and operating conditions in order to ensure the continued function of the equipment during all normal and reasonably foreseeable abnormal operating and fault conditions and to reduce the risk of:
- injury to embarked personnel;
- damage to the equipment, the system it is contained within or adjacent equipment and systems;
- damage to the ship;
- damage to third parties;
- pollution of the environment.

3.1.3 Essential services supplying the gas turbine package shall be continuously available or recoverable without compromising the safety of the gas turbine system following a single operational action or system/equipment fault.

3.1.4 Where the gas turbine package is required for the provision of essential services, the availability of these essential services is to be maintained by means of:
- reliability, especially of any single points of failure and taking into account factors such as erosion, fatigue, corrosion and mechanical damage due to vibration; and/or
- redundancy to minimise single points of failure, this is to be supported by the engineering safety and justification report required by 5.2.8.

3.1.5 The design, construction, installation and operation of the gas turbine package are to minimise the risk of fire.

3.1.6 The design, construction, installation and operation of the gas turbine package are not to cause interference or excessive forces that could lead to its failure or failure of other equipment and systems.

3.1.7 The gas turbine package is to be capable of continuous operation at its maximum rating in the conditions defined in Pt 1, Ch 2,4 or the ship's ConOps, whichever is the more onerous. Partial reductions in capability for operation in defined extreme conditions are subject to special consideration and the agreement of the Owner providing that essential services are maintained.

3.1.8 The materials of the gas turbine package and its components are to have adequate strength and adequate corrosion resistance for the stated design life with clearances appropriate to the operating temperatures.

3.1.9 The design of the gas turbine package, and the design of any fixed or portable equipment supplied to support maintenance and repair activities, is to be such that all maintenance and repair activities, including 'upkeep by exchange', can be undertaken effectively and safely.

3.1.10 Safe access is to be provided to the gas turbine package, including access provision in the event of equipment failure, fault finding and diagnostics.

3.1.11 The gas turbine package is to be provided with arrangements for control, monitoring, alert and safety systems that will maintain the package in a safe state throughout all normal and reasonably foreseeable abnormal operating and fault conditions.

3.1.12 All control, monitoring, alert and safety systems are to be compatible with, and be capable of interfacing with, the ship's Platform Management System.

3.1.13 Noise and vibration from the gas turbine package are to be attenuated to requirements of an appropriate standard, agreed by the Naval Administration.

3.1.14 The environmental conditions and atmosphere of the space containing the gas turbine unit are to be maintained during all normal and reasonably foreseeable abnormal operating and fault conditions, in a range which is acceptable for Operators and appropriate to equipment installed in the space.

3.1.15 Operators are to be provided with adequate information and instructions for the safe operation and maintenance of the gas turbine package, including information on potential failures that could lead to hazardous or major consequences and degradation in systems performance that could lead to failures.

■ *Section 4*
Verification requirements

4.1 Verification requirements

4.1.1 Compliance with the requirements in Sections 5 to 12 inclusive is deemed to satisfy the functional requirements and performance requirements above.

4.1.2 Where a designer offers a novel solution for which the requirements in Sections 5 to 12 are considered inappropriate, the designer may submit the novel solution to LR for consideration with a report setting out the justification that the functional requirements in Section 2 and the performance requirements in Section 3 have been satisfied.

■ *Section 5*
Particulars to be submitted

5.1 General

5.1.1 Unless otherwise advised, it is the responsibility of the system integrator or packager to agree the scope, functional requirements and boundary interfaces for the gas turbine package with LR and to prepare and submit the information required by this Chapter.

5.1.2 The following should be read in conjunction with Pt 1, Ch 2,3.

5.1.3 During the life of the gas turbine, details of any proposed changes that affect the safe and reliable operation of the gas turbine are to be submitted to LR for approval.

5.1.4 Where considered necessary by LR, additional documentation may be required.

5.2 Plans and information

5.2.1 A System Operational Concept document covering the propulsion system, *see* 1.1.8.

5.2.2 A System Design Description, *see* 1.1.9, for the gas turbine package, including references to the System Operational Concept document required by 5.2.1 and to Plans required by 5.2.4, is to be submitted so that the function of all essential and safety critical components and systems necessary for the turbine operation is clearly defined. This is to include a general overview of the operating principles supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the gas turbine capability and functionality under defined normal and reasonably foreseeable abnormal operating and fault conditions such as recovery from a failure, degraded modes of operation, or malfunction, with particular reference to the functioning of the control, monitoring, alert and safety systems and any subsystems.

5.2.3 Where a gas turbine unit may be required to operate for continuous periods outside its recommended continuous operating design envelope, details of the intended operating conditions, time intervals and frequency of use together with documentary evidence indicating the suitability of the design and any limitations under these conditions are to be included in the System Design Description required by 5.2.2. Arrangements may include time alongside, manoeuvring, close-down and other military operations or trials.

5.2.4 To assess compliance with the design requirements of the Rules and for inspection, installation and record purposes, the following are to be submitted for consideration:

(a) Plans:
  - Casing construction arrangement;
  - Arrangements of combustion chambers, intercoolers and heat exchangers;
  - Gas generator rotating components;
  - Control engineering systems, *see* Pt 9, Ch 1;
  - Inlet and exhaust ducting arrangement;

- Nozzles, blades and blade attachments;
- Power turbine components;
- Rotors, bearings and couplings;
- Section assembly;
- Securing arrangement, where applicable, including details of resilient mounts, *see also* Pt 1, Ch 2,3.3.6;
- Details of bleed air, anti-stall and surge systems or devices;
- Details of materials of all load bearing and torque transmitting components and pressure retaining parts;
- Details of materials for rotors and discs are to be submitted for approval;

(b) Schematics:
- Cooling and sealing air arrangements for compressor and gas generator components;
- Cooling water system;
- Fuel system;
- Gas turbine unit acoustic enclosure, if applicable, including fire, insulation, ventilation and drainage systems;
- Lubricating oil systems;
- Starting system;
- Machinery (safety) interlocks;

and, where applicable:
- Fire systems (Piping and Instrumentation diagram);
- Enclosure and base frame;
- Alternator;
- Highspeed coupling shaft.

5.2.5 Miscellaneous. Details of the following are also to be submitted:
(a) Operating manuals that describe the particulars of each system, including reference to the functioning of subsystems and with particular reference to any predicted adverse affects, e.g., fouling;
(b) Maintenance manuals that include declared lives of critical components and overhaul schedules recommended by the manufacturer;
(c) Fuel specifications and
(d) The maintenance and support arrangements by which the gas turbine unit is to be exchanged (where applicable).

5.2.6 Details of proposed welding procedures and proposals for the routine examination of safety-critical and/or structurally significant joints by non-destructive means are to be submitted for consideration.

5.2.7 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration and are to be agreed by the Owner. These are to include details of rotor balancing techniques, methods of determining the integrity of pressure casings and heat exchanger tests.

5.2.8 An engineering safety and justification report for the gas turbine unit defined in 1.1.2(a), stating design standards, assumptions and providing technical evidence. This is to be derived from a Risk Based Analysis in accordance with 5.2.9 and is to include, but is not to be limited to:
(a) Possible failure modes of internal components, to include such items as rotors, discs, seals, bearings and coupling, etc., and measures adopted to mitigate such failures that may have an effect on the internal machinery or the surrounding environment/structures/systems, taking due account of suitability of materials and the effects of stress raisers, etc.;
(b) Limiting operating parameters;
(c) Details of life-limited critical components, including their declared lives and residual lives or balance of planned life remaining, in terms of operating time or operating cycles, or where life is derived from declared acceptance criteria, and the associated maintenance strategies;
(d) Short-term high power operation;
(e) Details of mounting and securing arrangements;
(f) Rotor and blade vibratory characteristics;
(g) Details of potential failures that could lead to hazardous or major consequences and/or degradation in systems performance that could lead to failures and which are to be notified to the Operators;
(h) Common failure modes and system redundancy fitted to minimise potential single points of failure.

5.2.9 A Risk Assessment is to be carried out in accordance with the requirements of Pt 1, Ch 2,17 and is to include the following associated sub-systems:
(a) Starting and stopping;
(b) Fuel;
(c) Lubricating oil;
(d) Hydraulic oil;
(e) Cooling arrangements;
(f) Intercooler, where applicable;
(g) Air induction;
(h) Exhaust;
(j) Recuperator, where applicable;
(k) Gas turbine mounting;
(l) Electrical power supplies;
(m) Control systems;
(n) Safety systems;
(o) Ventilation;
(p) Fire protection (where applicable);
(q) Emissions abatement plant;
(r) Wet washing arrangements;
(s) Rotor turning arrangements.
It is not necessary to consider failure modes relating to the gas turbine components for the purposes of this Section.

5.2.10 For the gas turbine package components and system support services defined in 1.1.3(b), 1.1.3(c) and 1.1.4, the engineering safety and justification report defined in 5.2.8 is to include details of potential failures that could lead to hazardous or major consequences and/or degradation in systems' performance that could lead to failures and which are to be notified to the Operators.

5.2.11 Where applicable, the engineering safety and justification report defined in 5.2.8 is to include the fire protection arrangements specific to the package, including arrangements for the gas turbine enclosure (if provided), *see* Pt 1, Ch 2,3.3.15 and Pt 1, Ch 2,5.13.

5.2.12 Where the gas turbine is a prime mover in an electrical power generation system, the engineering safety and justification report defined in 5.2.8 is to include an assessment of the systems defined in 1.1.3(d), addressing requirements in Pt 10, Ch 1.

5.2.13 In addition to the applicable plans and particulars required by Pt 9, Ch 1, the following information for control, monitoring, alert and safety systems relating to the operation of an electronically controlled unit is to be submitted:

(a) Gas turbine package configuration details, *see* 10.11.1;
(b) Software quality plans, including configuration management documents;
(c) Software safety evidence;
(d) Software assessment inspection report such as SCA or IEC 61508, as applicable, which is to include the following as a minimum:
  - Identify the standards used for analysis and system design;
  - Identify the engine, its purpose and the associated objectives of the analysis;
  - Identify any assumptions made in the analysis;
  - Identify the equipment, system or sub-system, mode of operation and the equipment;
  - Identify potential failure modes and their causes;
  - Evaluate the local effects (e.g., fuel injection failure) and the effects on the system as a whole (e.g., loss of propulsion power) of each failure mode;
  - Identify measures for reducing the risks associated with each failure mode (e.g., system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.,);
  - Identify trials and testing necessary to prove conclusions.

5.3 Calculations and specifications

5.3.1 The following calculations and specifications are to be submitted. Where appropriate, this information can be included in the System Design Description required by 5.2.2:
(a) Vibration analysis and alignment analysis as required by this Chapter;
(b) The material specifications, including the minimum specified tensile strength of each shaft and coupling component, are to be stated;
(c) Details of the gas turbine manufacturer's requirements for air inlet filtration, including maximum allowable inlet pressure drop, and of the maximum allowable exhaust depression. Air intake and uptake arrangements, with calculations demonstrating that the intake and uptake designs satisfy those requirements, are to be submitted for consideration;
(d) Where a gas turbine package includes components having a specified life in terms of operating time or operating cycles, or where life is derived from declared acceptance criteria, details are to be submitted for consideration. Details of proposed arrangements for monitoring life progression are to be submitted for consideration;
(e) Statement indicating the suitability of flexible hoses;
(f) Flexible hose and bellows expansion piece registers selected for use in the package, *see* Pt 1, Ch 2,4.19;
(g) Machinery fastening:
  - Documentary evidence and calculations indicating that machinery is mounted securely for the ship's motions and accelerations, including shock, to be expected during service;
  - Calculations to demonstrate that mountings can withstand the design shock acceleration without fracturing;
  - Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type and design of mounts;
  - Natural frequency calculation of resiliently mounted machinery;
  - Mass and centre of gravity for the gas turbine and related equipment.

5.3.2 Vibration and alignment calculations and specifications are to be submitted as part of the propulsion system requirements. *See* Pt 3, Ch 2.

■ *Section 6*
Materials

6.1 Material tests and inspection

6.1.1 Components are to be tested in accordance with the relevant requirements of the Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

6.1.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 7*
Design and construction

7.1 General requirements

7.1.1 **Application.** This Chapter is to be read in conjunction with the requirements of Pt 1, Ch 1 and Pt 1, Ch 2.

7.1.2 **Basic requirements.** Designs are to take account of the potential effects of system and component malfunction and variability in characteristic values.

7.1.3 The design shall account for the operating conditions specified in Pt 1, Ch 2,4 or the ship's ConOps, whichever is the more onerous, and is to include those for static and dynamic loads and deflections, including for relative motions between elements of the gas turbine package and with the ship and other equipment, due to thermal expansion, vibration, etc., over all normal and reasonably foreseeable abnormal operating and fault conditions, including for fault condition loadings arising in the propulsion shaft line/alternator.

7.1.4 The gas turbine unit is to be capable of operating at defined power ratings with a range of fuel compositions/grades specified by the Owner/Operator and agreed by the gas turbine manufacturer.

7.1.5 The space containing the gas turbine unit shall comply with the requirements of Pt 1, Ch 2,5.

7.1.6 Where applicable, the mounting/support arrangements of the gas turbine system are to satisfy the shock capability requirements defined by the Naval Administration. *See* Pt 1, Ch 2,3.3.11.

7.1.7 The fatigue life of dynamically loaded components is to be considered with respect to defined operating conditions, expected usage and maintenance policy, *see* Section 12. Due account is to be taken of stress raisers and material properties.

7.1.8 Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet those of Pt 12, Ch 1. Where secondary exhaust gas emissions abatement systems are fitted to gas turbines, they are to meet the requirements of Pt 12, Ch 1.

7.2 Vibration

7.2.1 The gas generator and power turbine rotors are not to exhibit levels of vibration within the normal speed range that exceed the requirements of the Owner or that result in a failure to meet engine design life.

7.2.2 Vibration monitoring is to form an integral part of the gas turbine control, monitoring, alert and safety system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shut down the gas turbine, before an over-critical situation occurs, i.e., multiple rotor blade or disc release.

7.3 Containment

7.3.1 Gas turbines and power turbines are to be designed and installed to contain debris within the unit in the event of release of a rotor blade or other rotating component of equivalent kinetic energy on release.

7.3.2 In the event of any component failure where the engine casing may not contain the debris, fuel, lubricating oil and other potentially hazardous systems or equipment are to be located outside the planes of those high-speed rotating parts identified as a potential loss of containment hazard by the engineering safety and justification report. Where this is not possible, they are to be suitably protected. This requirement also applies to fire detection and fire-extinguishing equipment.

7.3.3 Gas turbine ancillaries containing flammable products are to be segregated or protected from high temperature areas.

7.3.4 Means are to be provided such that, in the event of a failure to a shaft or coupling, the occupants of the ship are not endangered, either directly or through damage to the ship or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

7.4 Intake and exhaust ducts

7.4.1 The air intakes and exhausts are to be in accordance with the turbine manufacturer's design requirements. Particular attention is drawn to the requirements on pressure and flow conditions to be achieved throughout the intake and exhaust systems. Arrangements are to comply with 7.4.2 to 7.4.13, as applicable.

7.4.2 Where multiple gas turbines are installed, each gas turbine unit is to have separate intakes and exhausts so arranged as to prevent induced circulation through a stopped gas turbine unit.

7.4.3 Intakes and exhausts are to include suitable means of access to carry out inspections, maintenance and/or repair of components as advised by the gas turbine manufacturer. Any access panels should be sealed suitably to maintain the desired pressure and flow conditions in the intake and exhaust.

7.4.4 Suitable intake filtration is to be provided to control the ingestion of water, particulate and corrosive marine salts within the gas turbine manufacturer's specified limits.

7.4.5 Where an air intake enclosure forms the connection between the ship's downtake and the gas turbine package, a suitable alarm function is to be provided to give warning when an unacceptable air intake pressure loss is reached at the air inlet (bellmouth) of the gas turbine.

7.4.6 Intakes are to be designed such that material cannot become detached due to air flow or corrosion. Fixing bolts and fastenings are to be positively locked so that they cannot work loose.

7.4.7 The exhaust system is to accommodate thermal expansion and movement of the duct due to the combined effects of operation of the gas turbine and flexure of the ship's structure.

7.4.8 The design of exhaust systems is to prevent deterioration of engine parts resulting from ingress of sea or rainwater through the exhaust ducting when the gas turbine is not in use. Drainage arrangements are to be provided and are to be led to a tank suitable for the potentially corrosive nature of any drainage.

7.4.9 The exhaust ducting is to be designed and installed to minimise the risk of unburnt fuel collecting inside the duct.

7.4.10 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes.

7.4.11 The exhaust system is to be arranged so that hot exhaust gases are directed to avoid impingement on equipment and away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

7.4.12 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back into the gas turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion-resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end with suitable arrangements made to prevent water flooding the machinery space.

7.4.13 The design of exhaust systems is to take account of any noise hazards to personnel, ensuring that they are within specified requirements for the ship.

7.4.14 The design of exhaust gas waste heat recovery recuperators for combustion air heating is to be compatible with the installed engine design parameters. The parameters which influence the build up of soot deposits and overheating such as fuel, exhaust gas temperature and efflux velocity are to be considered in the design of the recuperator in order to minimise the risk of fire and breakdown during operation. The engineering safety and justification report required by 5.2.8 is to also demonstrate compliance with these requirements or alternative means of preventing the accumulation of soot or overheating, such as the use of exhaust gas by-pass ducting with automatic flap valve arrangements and/or effective soot prevention and cleaning systems for installations which use recuperators. Waste heat recovery units for steam generation are to meet the requirements of Pt 8, Ch 1,1.13.

7.5 Thermal insulation

7.5.1 Suitable provision is to be made to protect personnel and equipment and to minimise the risk of fire from any surfaces of the gas generator, power turbine and/or exhaust volute that exceed a temperature of 220°C during operation.

7.6 Welded construction

7.6.1 Welding processes are to be in accordance with the requirements of the Rules for Materials.

7.7 Anti-stall/surge systems

7.7.1 Air bleed (blow off) valves and/or variable geometry mechanisms are to be fitted as required to maintain compressor surge margins throughout the operating range. Any open-ended air bleed arrangements are to be led to the uptake or atmosphere and not into the machinery space; the back pressure imposed by the ducting is to be in accordance with the turbine manufacturer’s recommendations.

7.7.2 The design of anti-surge and anti-stall systems is to take account of any noise hazards to personnel, ensuring they are within specified requirements for the ship.

7.8 Emergency operation

7.8.1 Where a gas turbine is required for the provision of essential services, it and its supporting service systems are to be capable of operation when the compartment is flooded to the level of the underside of the lowest exposed portion of the gas turbine casing.

■ *Section 8*
Gas turbine package sub-systems

8.1 Piping systems

8.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 7, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 The gas turbine design and construction are to minimise the possibility of a fire fed by fuel or lubricating oil leaks.

8.1.3 Any flexible hose assemblies are to comply with Pt 7, Ch 1,13.

8.2 Fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 7, Ch 3,3.9; gas fuel supply arrangements are to comply with the requirements of Pt 7, Ch 1.

8.2.2 Any high-pressure fuel delivery lines between the fuel pumps and fuel metering valves that are external to the enclosure are to be of double walled construction and are to be capable of containing fuel from a high-pressure line failure to prevent fuel, or oil fuel mist, from reaching a source of ignition on the gas turbine or its surroundings.

8.2.3 Suitable arrangements are to be made for draining/venting any fuel leakage from the protection required by 8.2.2 and to prevent contamination of the lubricating oil by oil fuel. An alarm is to be provided to indicate that leakage is taking place.

8.2.4 Means are to be provided to purge the fuel system of air.

8.2.5 Gas turbine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. Connections on such piping systems should be chosen to minimise the risk of pressurised fuel leaks.

8.2.6 Where more than one gas turbine is supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. These means of isolation are not to affect the operation of the other gas turbine(s) and are to be operable from a position not rendered inaccessible by a fire on any of the engines, *see* also Pt 1, Ch 2.

8.3 Lubricating oil systems

8.3.1 Lubricating oil arrangements for the gas turbine system and, where applicable, the alternator, are to comply with the requirements of Pt 7, Ch 3,8. They are to be configured to provide adequate flows of lubricating oil to all bearings in the gas turbine unit and, where applicable, the alternator, over the whole range of normal operation and reasonably foreseeable abnormal operating and fault conditions, including start-up and shutdown (run-down) periods.

8.3.2 Where the lubricating oil is circulated under pressure, provision is to be made for the efficient filtration of the oil. At least two filters are to be fitted in the lubricating oil supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered lubricating oil to the gas turbine.

8.3.3 Gas generator and power turbine bearings are to be arranged such that lubrication is not affected adversely by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

8.4 Ventilation and cooling systems

8.4.1 Air cooling and/or ventilation arrangements are to comply with the requirements of Pt 1, Ch 2,5.7 and 5.12.

8.4.2 Cooling water arrangements are to comply with the requirements of Pt 7, Ch 3, as applicable.

8.5 Turning gear

8.5.1 Turning gear is to be provided to facilitate operation and maintenance of the gas turbine unit as required by the manufacturer.

8.5.2 Gas generator turning gear may be hand-operated where hand operation is practicable. Where turning gear is electrically driven, the motor is to be rated continuously to turn the rotor for an indefinite period with no restrictions. Manuals are to be provided and are to comply with the requirements of Pt 1, Ch 1,4.6.7.

8.5.3 The turning gear is to be fitted with safety interlocks which prevent gas turbine operation when the turning gear is engaged, *see* Pt 1, Ch 2,4.14. Indication of engaged/disengaged is to be provided at all start positions. In the case of hand-operated turning gear, turbine operation may be prevented by manual means, including the provision of warning devices or notices.

8.5.4 The remote control of power-driven turning gear is to be designed so that power is removed if the operating switch is released.

8.5.5 If permanently attached, means are to be provided to secure the turning gear when disengaged.

8.5.6 Overload protection arrangements are to be provided to prevent damage to the turning gear train. Where the turning gear is electrically driven, the protection system is to comply with Pt 10, Ch 1.

8.6 Power take-off coupling shafts

8.6.1 Power take-off shafts coupling the power turbine to the main gearbox/generator are to comply with the requirements for such intermediate shafts given in Pt 3, Ch 2, due regard being paid to the particular type of installation.

8.7 Installation

8.7.1 Drainage arrangements for package components are to link to ship's drains, taking due account of the materials involved (wash water, fuel, lubricating oil, etc.,). Where applicable, those arrangements are not to compromise any requirements to operate the space containing the gas turbine unit at pressures above/below atmospheric ambient.

8.7.2 The ventilation arrangements for the space containing the gas turbine system are to provide sufficient air flow to ensure that the temperatures of components are maintained within the limits specified by the supplier for all normal and reasonably foreseeable abnormal operating and fault conditions.

8.7.3 Where the gas turbine unit is subject to a process of 'upkeep by exchange', the lifting arrangements that form part of the installation and/or provisions for the attachment of lifting gear within the installation shall conform to the requirements of a recognised Standard for lifting appliances.

8.7.4 Machinery is to be mounted to provide adequate support against ship motions and relative movement between items of equipment and, where required, protection against shock in accordance with Naval Administration requirements, and to attenuate the transmission of noise and vibration to meet the specified requirements. The requirements of Pt 1, Ch 2,5.5, are to be satisfied.

8.8 Fire protection

8.8.1 Where the package includes a dedicated fire protection system to protect against fire in the gas turbine unit and its ancillaries, that system is to meet the requirements of Pt 1, Ch 2,5.13.

8.8.2 Where the gas turbine is installed inside a dedicated enclosure, the enclosure boundary is to provide an appropriate level of fire protection, containing/limiting the spread of flames and smoke. An engineering assessment of this boundary demonstrating that the installation meets the levels of fire safety demanded of the ship is to be provided as part of the Assurance Case, *see* 5.2.10.

■ *Section 9*

Starting arrangements

9.1 General

9.1.1 The operating conditions under which provision for starting gas turbines is required are to be defined in the System Operational Concept document.

9.1.2 Where a gas turbine is required for the provision of essential services, equipment for initial starting of the gas turbine is to be provided and arranged such that the necessary initial charge of starting air, hydraulic or electrical power can be developed on board the ship without external aid.

9.1.3 Alternatively, other devices of an approved type may be accepted as a means of providing the initial start.

9.1.4 Where the integrity of the starting system is susceptible to overspeed conditions, appropriate alarm and/or trip functions are to be provided.

9.2 Purging before ignition

9.2.1 Means are to be provided to clear all parts of the gas turbine of any accumulation of fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

9.3 Air starting

9.3.1 Where the gas turbine is arranged for air starting, the air start system is to comply with the requirements set out in Pt 2, Ch 1,7.13. The total air receiver capacity is to be sufficient to provide, without replenishment, no fewer than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided to satisfy the plant air start requirements. For requirements regarding air receivers, *see* Pt 8, Ch 2.

9.3.2 For installations of more than one gas turbine, three consecutive starts per gas turbine are required.

9.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C.

9.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves, not fusible plugs.

9.3.6 Exhaust from the air start system is to be arranged so as not to present a hazard to the crew.

9.4 Starting air pipe systems and safety fittings

9.4.1 Starting air pipe systems are, in general, to comply with the requirements of Part 7, with due regard being paid to the particular type of installation.

9.4.2 When designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

9.4.3 The air discharge pipe from the compressors is to be led directly to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

9.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

9.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

9.4.6 The starting air pipe system is to be protected against the effects of explosions by the provision of an isolating non-return valve or equivalent at the starting air supply to each unit.

9.4.7 Alternative arrangements are subject to special consideration.

9.5 Electric starting

9.5.1 Where the gas turbine is arranged for electric starting, the arrangement is to be equipped with two independent power sources with one source protected against depletion. In all cases the electrical systems forming the starting system are to comply with the requirements of Pt 10, Ch 1.

9.6 Hydraulic starting

9.6.1 Where the gas turbine is arranged for hydraulic starting, then either the hydraulic pressure capacity of the power pack is to be sufficient to provide the number of starts of the gas turbine as required by 9.3.1 or 9.3.2, or the hydraulic power pack is to be supplied by two independent sources of electrical power, one of which is to be suitably protected against depletion.

■ *Section 10*

Control, monitoring, alert and safety systems

10.1 General

10.1.1 Control, monitoring, alert, safety and programmable electronic systems are to comply with the requirements of this Section and Pt 9, Ch 1.

10.1.2 The control system is to ensure safe and effective operation of the gas turbine package through the monitoring and control of critical parameters, such as engine speed, temperatures and pressures.

10.1.3 Each gas turbine is to be configured for the specified performance and is to satisfy the relevant requirements for mechanical drive or electrical generator applications.

10.1.4 The arrangements for control, monitoring, alert and safety systems are to be provided with a suitable back-up power supply to ensure that the gas turbine package can be shut down in a safe and controlled fashion upon loss of its primary and, where applicable, secondary electrical power supplies.

10.1.5 Interlocks are to be provided to prevent any operation of the gas turbine unit under conditions that could be hazardous to the machinery and/or personnel. The interlock system is to be arranged to be 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis of the complete installation.

10.2 Overspeed protection and shutdown system

10.2.1 The gas turbine is to be protected against overspeed by the provision of a suitable device(s) and software functions capable of shutting down the gas turbine safely before a hazardous overspeed condition occurs.

10.3 Speed governors

10.3.1 For each gas turbine that provides mechanical drive to propulsion device(s), a speed governor independent of the overspeed protective device is to be fitted. The speed governor's set limits are to be adjusted so that the speed does not exceed the limits which bring the overspeed protective device into action, *see* 10.2.1.

10.3.2 For each gas turbine intended for driving an electric generator, a speed governor, independent of the overspeed protective device is to be fitted. The speed governor's fixed settings are to control the gas turbine speed within the design limits of the electrical system requirements, as defined in the electrical System Operational Concept document.

10.4 Power turbine inlet over-temperature control

10.4.1 The power turbine is to be protected against overtemperature by the provision of a suitable device(s) capable of controlling the temperature within acceptable limits or shutting down the gas turbine safely to prevent damage.

10.5 Flame out

10.5.1 Indication is to be provided for identifying flame out and failure to ignite conditions for each combustion chamber, *see also* 9.2.1.

10.6 Lubricating oil system

10.6.1 Means are to be provided to determine accurately the pressure or flow of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems, to ensure safe operation.

10.6.2 Means are to be provided to determine accurately the temperature of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems, to ensure safe operation.

10.6.3 Means are to be provided to ensure that the temperature of the lubrication oil supply is controlled automatically to maintain steady-state conditions throughout the normal operating range of the gas turbine.

10.6.4 Where the lubrication oil supply to the power turbine is fed from a separate supply system, similar arrangements to those detailed above are to be provided.

10.7 Stopping of gas turbines

10.7.1 Means are to be provided, at both the local and remote control/operating positions, to initiate manually the shutdown of the gas turbine in an emergency.

10.7.2 In addition to 10.7.1, a means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station where the station is remote from the gas turbine control/operating position.

10.7.3 *See also* Pt 1, Ch 1,4.1.1 for requirements for stopping machinery from a position outside the compartment where the machinery is located.

10.8 Indication of temperature

10.8.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

10.9 Automatic and remote controls

10.9.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require manual intervention by the Operators, they are required to be provided with alarm and safety arrangements required by 10.9.2 and Table 2.10.1, as appropriate. Alternative arrangements which provide an equivalent level of safety will be considered.

10.9.2 Where oil fuel grades require heating or cooling only, oil fuel supply is to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine, *see also* 10.9.4.

10.9.3 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in Table 2.10.1, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be functionally independent of those required for the first stage alarm, in that failure in one cannot affect the functionality of the other.

10.9.4 Where the oil fuel supply is heated, automatic control for viscosity may be fitted in place of the temperature control required by 10.9.2.

Table 2.10.1 Gas turbine machinery: Alarms and shutdowns

Item	Alarm	Note
Overspeed	High	Automatic shutdown, *see also* 10.2
Power turbine inlet temperature *See* Note 4	1st stage high 2nd stage high	Automatic power reduction Automatic shutdown, *see also* 10.4
Flame failure Failure to ignite	Failure Failure	Automatic shutdown, *see also* 10.5 Automatic shutdown, *see also* 10.5
Turbine vibration	1st stage high 2nd stage high	— Automatic shutdown
Uptake temperature	High	To monitor for soot fires *See* Notes 5 and 6

NOTES
1. For two-stage alarms, *see also* 10.9.3.
2. For requirements on purging before ignition, *see* 9.2.
3. Where there are separate lubricating oil systems for gas generator and power turbine/gearing sections, each system is to be monitored.
4. Where there is more than one combustion chamber, the temperature of each chamber is to be monitored.
5. Alarm only required when suitable for operation on residual fuel grades and an exhaust gas economiser/boiler/thermal oil heater is fitted.
6. Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.
7. The Table contains the minimum list of alerts and shutdowns for a gas turbine; additional alerts and shutdowns may be necessary as determined through risk-mitigating activities in response to the completed Risk-Based Analysis (e.g., FMECA) for the gas turbine.
8. If certain alarms and shutdowns are not applicable for the gas turbine, sufficient evidence shall be produced to support the claim (e.g., Risk-Based Analysis such as FMECA).

10.10 Sensors

10.10.1 Sensors are to be selected with regard to their accuracy and integrity. For measurements required for safety functions, an engineering assessment is to be presented justifying the sensor configuration adopted. This assessment is to address any self-testing by the control system that is used to monitor the health of those sensors.

10.10.2 Where multiple sensor arrays are used to provide the necessary levels of reliability and integrity, the control system is to use the value that provides the greatest margin of safety.

10.11 Control engineering systems

10.11.1 The engine control, monitoring, alert and safety systems are to be configured to comply with the relevant requirements (e.g., operating profile, alarms, shutdowns, etc.,) of this Chapter and Pt 9, Ch 1 for an engine for main or auxiliary power purposes. Details of the engine configuration are to be submitted for consideration identifying:
(a) Local and remote means to carry out system configuration.
(b) Engine packager or system integrator procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g., Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion or auxiliary engine application.
Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request, in accordance with Pt 9, Ch 1.

10.12 Software

10.12.1 Where a software-based system forms part of a control, monitoring, alert and safety system, it is to comply with the requirements of Pt 9, Ch 1.

■ *Section 11*
Survey and testing

11.1 Construction principles

11.1.1 Construction is to be in accordance with plans approved by LR and in accordance with the requirements of the relevant parts of the Rules, *see* Pt 1, Ch 2,8.

11.1.2 Where required by these Rules, items are to be constructed under survey.

11.1.3 Materials are to be approved, manufactured and tested in accordance with a standard acceptable to LR.

11.1.4 Satisfactory operation and load testing is to be witnessed by LR where required by the Rules.

11.1.5 The elements of the package listed in Table 2.11.1 are, as applicable, to be certified as shown.

Table 2.11.1 Gas turbine machinery: Certification requirements

Component	Certificate	Standards
Gas turbine unit	Type Approval Certificate Engine Construction Certificate	LR Test Spec GTA04 Naval Ship Rules
Engine fluid systems	Design Appraisal Document Package Construction Certificate	Naval Ship Rules
GT Lubrication Module	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Fuel systems	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Control System Hardware	Type Approval Certificate Type Test Certificate	LR Test Spec 01
Control System Software	Design Appraisal Document Package Construction Certificate	LR Software Conformity National Standards Naval Ship Rules
Engine Mounts	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Package Mounts	Manufacturer's Certificate	National Standards
Enclosure and Base frame (as appropriate)	Design Appraisal Document Package Construction Certificate	Naval Ship Rules SOLAS
Cooling/ventilation systems	Design Appraisal Document Package Construction Certificate	Naval Ship Rules National Standards
Fire protection system (FPS)	Design Appraisal Document Type Approval Certificates Package Construction Certificate	Naval Ship Rules SOLAS FSS Code
Fire Insulation Arrangements	Design Appraisal Document Type Approval Certificates Package Construction Certificate	Naval Ship Rules FTP Code
Start system	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Intake assembly	Manufacturer's Certificate	National Standards
Exhaust collector	Manufacturer's Certificate	National Standards
Coupling shaft (where applicable)	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Alternator Lubrication Module (where applicable)	Design Appraisal Document Equipment Certificate	Naval Ship Rules

■ *Section 12*
Planned maintenance and condition monitoring procedures, and 'upkeep by exchange'

12.1 Planned maintenance approach

12.1.1 Suitable gas turbine package, Planned Maintenance and Condition Monitoring Schemes (PMS(CM)), will be accepted as part of LR's Continuous Survey Machinery (CSM) cycle, provided the principles defined in 12.2 to 12.4 are satisfied.

12.2 Preventive maintenance

12.2.1 Preventive maintenance requires items to be opened for inspection by removing inspection covers or partial disassembly as appropriate, by using probes or by direct observation, and overhaul at specified time periods or after a specified number of running hours.

12.2.2 Maintenance is normally carried out irrespective of the condition of the gas turbine package components in order to retain the package in a satisfactory operational condition.

12.3 Unscheduled maintenance

12.3.1 The planned maintenance scheme is to be capable of dealing effectively with breakdown or corrective maintenance, i.e., unscheduled maintenance.

12.4 Condition monitoring

12.4.1 The conditioning monitoring techniques to support the trend away from preventive maintenance, are listed in Table 2.12.1. They are considered the minimum acceptable to obviate the need for a fully opened out inspection of engine components at Periodical Survey.

12.4.2 Alternative arrangements to those in Table 2.12.1, which provide an equivalent level of confidence in the condition of the gas turbine package, will be considered.

Table 2.12.1 Condition monitoring techniques

Method	Requirement
Visual inspection	Periodic inspection of intakes and exhaust ducts, inlet guide vanes, compressor 1st stage, compressor and gas generator casings and auxiliary components and systems. The running clearances and dimensional changes, where practicable
Visual inspection by borescope/endoscope	Periodic inspection of compressor stators, guide vanes and blades, combustion chambers, turbine nozzles and blades and power turbine
Vibration monitoring	Continuous monitoring and trend analysis of gas generator and power turbine rotor vibration. The equipment used for vibration measurement should be capable of determining vibration throughout the operating range of the gas turbine
Lubrication, oil trend analysis programme	• Periodic inspection of magnetic particle detectors (manual records and/or automatic recording via debris counters in oil scavenge lines) • Periodic inspection of oil filters • Periodic sampling and laboratory analysis of lubricant quality
Fuel quality	• Maintenance of oil fuel bunker/marine gas oil analysis records • Periodic sampling and laboratory analysis of fuel quality
Performance monitoring	Continuous monitoring and trend analysis of critical gas turbine operating parameters including: • Compressor conditions (inlet and exit temperature, delivery pressure and speed) • Power turbine (inlet entry temperature and speed) • Engine breather temperature • Low cycle fatigue counter *See* Note
NOTE Manual recording and trend analysis methods may also be acceptable.	

12.5 'Upkeep by exchange'

12.5.1 Where the gas turbine is maintained using an 'upkeep by exchange' policy, the requirements in Pt 1, Ch 1,6.10 are to be satisfied. Details of the arrangements by which the gas turbine unit is to be exchanged are to be submitted to LR for approval.

Section numbering in brackets reflects any Section renumbering necessitated by any of the Notices that update the current version of the Rules for Naval Ships.

Volume 2, Part 7, Chapter 3

8.6.4 Pt 2, Ch 2,5.1 *now reads* Pt 2, Ch 2,10

Volume 2, Part 7, Chapter 5

9.1.3 Pt 2, Ch 2,6 *now reads* Pt 2, Ch 2,9.3

Volume 2, Part 10, Chapter 1

6.9.2 Pt 2, Ch 2,7.3.4 *now reads* Pt 2, Ch 2,2.1.1

Volume 3, Part 1, Chapter 2

3.5.7 (a) Vol 2, Pt 2, Ch 2,8 *now reads* Vol 2, Pt 2, Ch 2,10.2.1

3.5.7 (b) Vol 2, Pt 2, Ch 2,8 *now reads* Vol 2, Pt 2, Ch 2,10.4.1

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